

Final Report
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The Center for Research on the Changing Earth System (CRCES)
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Proposal title: An Assessment of the Hydrologic Vulnerability of the Missouri River Basin to Climate Variability at Interannual to Decadal Timescales

The scientific objectives of the proposed research are:

1. To identify impacts of global-scale interannual and decadal timescale climate variability, especially ENSO, its decadal variability, and the Pacific Decadal Oscillation (PDO) on the hydro-meteorology of the MRB;
2. To identify hydrologic responses to this hydro-meteorological variability;
3. To identify impacts of this hydro-meteorological variability on yields of dryland and irrigated crops in the MRB;
4. To evaluate impacts of the above on demand for and supply of water for irrigation; and
5. To calculate the first-order economic effects of 4 and identify further societal impacts on the MRB region.

CRCES is well on the way to meeting the objectives of the proposal as described briefly in the following paragraphs.

Analyses of impacts of interannual and decadal climate variability on MRB hydro-meteorology

We found that three decadal climate variability (DCV) phenomena (i.e., the Pacific Decadal oscillation (PDO), the tropical Atlantic gradient (TAG) oscillation, and the Indo-Pacific Warm Pool (WP) variability) have significantly impacted the hydro-meteorology of the MRB. Records available from 1950 to 2000 show that decadal droughts and floods in that region are attributable to combinations of phases of these three DCV phenomena.

The reconstructed precipitation and surface air temperature anomalies associated with the PDO and the TAG during the mid-to-late 1980s droughts, based on regressions between each DCV index and the MRB hydro-meteorological anomalies show that there was a small increase in precipitation in the MRB associated with the warm PDO phase, but a large decrease in precipitation was associated with the cool TAG phase. There was approximately 0.2°C cooling over much of the MRB associated with the warm PDO phase, and there was approximately 0.3°C warming in the northern MRB and approximately 0.3°C cooling in the southern MRB associated with the cool TAG phase. These combined precipitation and surface air temperature anomalies resulted in decadal droughts in the MRB in the mid-to-late 1980s. A manuscript (Mehta and Rosenberg, 2008) based on these results is being prepared for publication in *Journal of Hydrometeorology*.

Simulation of impacts of interannual and decadal climate variability on yields of dryland crops in the MRB

The Erosion Productivity Impacts Calculator model (EPIC, Williams, 1995; Thomson et al., 2005a) is used in our current study to simulate yields of dryland corn, winter wheat, spring wheat, sorghum, and soybeans in the MRB states. Taking into account the increasing yields due to improving agricultural technology since 1950, we found that departures of crop yields from the increasing average yields were well-simulated and that these departures can be largely attributed to the three DCV phenomena mentioned above. Our analysis indicates that the cool (or negative) phase of the TAG, associated with below-average summer precipitation in the MRB in the mid-to-late 1980s, was associated with below-average soybean yield. The warm (or positive) phase of the PDO was associated with above-average summer precipitation and above-average soybean yield in Kansas. A generally similar behavior of corn yields was found in South Dakota also in our simulation. Thus, major DCV phenomena appear to make significant impacts on hydro-meteorology and crop yields in the MRB. A manuscript (Rosenberg and Mehta, 2008) based on these results is being prepared for publication in *Journal of the American Water Resources Association*.

The same approach is currently being applied to natural water flows through use of the Hydrologic Unit Model of the United States (HUMUS) modeling system. Results are not yet available for inclusion in this report.

Assessment of decadal climate information needs of stakeholders and policymakers in the MRB

In December 2006, a representative cross-section of Nebraska stakeholders and policymakers was interviewed by the project researchers to gather information about their perceived needs for climate information. Discussions were held with over 30 local and regional water managers, policymakers, farmers, and researchers in Nebraska and western Iowa.

Some of the major organizations represented in this study were Central Nebraska Public Power and Irrigation District, Bureau of Reclamation, Army Corps of Engineers, Nebraska Farm Bureau, Tri-Basin Natural Resource District, National Park Service, and various departments and centers within the University of Nebraska–Lincoln system. These stakeholders', policymakers', and academic researchers' very positive and articulate responses to our questions led to the following major conclusions: (1) impacts of persistent, decadal, hydro-meteorological anomalies are qualitatively different compared to impacts of year-to-year anomalies; (2) agriculture, water resources for municipalities, power plants, and navigation in the MRB are much more vulnerable to decadal drought events than to year-to-year events; (3) there is an evident need for decadal drought outlooks; (4) any particular DCV-related drought/flood event can have differing sectoral and economic impacts in the various geographical portions of the MRB (e.g., recreation in Montana and the Dakotas, irrigation in Nebraska and Kansas, and navigation in the downstream States); (5) municipalities and industry, particularly power generation, are sensitive to drought/flood-related changes in water supply everywhere in the MRB; (6) farms along the Missouri River are much more vulnerable to persistent floods than to persistent droughts; (7) while crops are, of course, sensitive to changes in weather associated with year-to-year hydro-meteorological anomalies, modern crop breeding is increasing their resilience to short-term climate variations; (8) the addition of new dimensions to research are necessary, such as the need

to include groundwater in total impacts of droughts/floods on water availability and very important impacts on unmanaged ecosystems, and in land-use, such as areas being driven at this time by the Conservation Reserve Program and the introduction of biomass cropping; and (9) a much more detailed study, with questions focused on individual groups and a wider range of economic sectors, is needed for the entire MRB.

A CRCES Report (Rosenberg et al., 2007), based on these discussions with stakeholders and policymakers in Nebraska, was prepared and submitted to NOAA-SARP program in June 2007.

Employment and training

One research assistant were employed and trained under this grant. The PIs, CRCES's Administrative Officer, a consultant were partially supported by this grant. Travel and meeting costs of project researchers with stakeholders and policymakers in Nebraska were also supported by this grant.

Refereed publications

Mehta, V.M., and N.J. Rosenberg, 2008: Impacts of decadal climate variability on the Missouri River Basin hydro-meteorological variability in Northern Hemisphere summer. In preparation for *J. Hydromet.*

Rosenberg, N.J., and V.M. Mehta, 2008: Impacts of decadal climate variability on water resources and agriculture in the Missouri River Basin. In preparation for *J. the American Water Resources Association*.

Other publications

Rosenberg, N.J., V. M. Mehta, M. J. Hayes, C. Knutson, and M. Sittler, 2007: Decadal climate information needs of stakeholders and policymakers in the Missouri River basin. *Report of an elicitation trip to Nebraska*; Submitted to NOAA in June 2007.

Workshop/Conference presentations:

Mehta, V.M., and N.J. Rosenberg, 2007: Evolving climate and its impacts on Great Plains water. *Conference on the Future of Water Use in Agriculture*, Lincoln, Nebraska; 26 March 2007.

Mehta, V.M., N.J. Rosenberg, and K. Kullgren, 2007: Decadal variability of the tropical climate and its impacts on Missouri River basin water resources and agriculture: The roles of precipitation variability as cause and effect. *European Geosciences Union Assembly*, Vienna, Austria; 17 April 2007.

Mehta, V.M., N.J. Rosenberg, and K. Kullgren, 2007: Decadal climate variability impacts on water resources and agriculture in the Missouri River basin. *The CRCES Workshop on Societal Impacts of Decadal Climate Variability in the United States*, Waikoloa, Hawaii; 26-29 April 2007.